# APPLICATION COVER SHEETS

Date: 4/19/02

**Applicant Information**


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**Budget/Funding Information**

12 month anticipated budget ≈$50,000

**Project Title: Cereal Straw Utilization for Paper**

"Improve the Environmental Impacts Associated with Forestry Practices and with Cereal Grain Production: Demonstrate to Paper Consumers, Paper Producers and the Public the Benefits of Replacing Wood by Agricultural Residues in Paper"

## Project Summary

The proposed work described in this Grant Application will develop technical information to help a pulp and paper manufacturing facility plan for a short term, full size mill trial using cereal straw as a part of the raw material mix. This trial would partially substitute cereal straw for wood pulp in corrugated medium (fluting in cardboard boxes). The quantity of material produced would be sufficient for broad distribution to corrugated medium consumers. Also, newsprint made from semi-bleached agfibers will be used to manufacture newsprint. This newsprint will be supplied to newsprint manufactures and publishers in eastern Washington to show the viability of agfiber newsprint. In addition, the project will begin discussions with targeted paper consumers and regional paper manufacturing firms and with public agencies, including media and nonprofits, about the economic and environmental advantages resulting from incorporations of agricultural residues into paper products.

This project will also show the viability of an integrated agfiber cooperative between the pulp manufacturer and the farmer. The farmer supplying the straw, and the pulp manufacturer supplying spent liquors for fertilization of the fields.

## Anticipated Outcomes in the Project Year

- Create a demand for paper products containing pulp derived from agricultural residue(wheat, grass, alfalfa, and barley straw).
- Transform underutilized cereal straw into higher value products. Enhance the income flow to the Washington state agricultural industry.
- Reduce the amount of atmospheric $CO_2$ emissions originating from field burning of cereal straw
- Remove cereal straw from fields, which will permit broader use of No-Till systems. This will reduce $CO_2$ emissions originating from combustion fuels in farm equipment.
- Optimize bleaching sequences on the various straws to determine which straw would best be utilized in a subsequent grade of paper.
- Evaluate wheat, grass, alfalfa, and barley for pulp strength and optical properties.

## BACKGROUND AND RATIONALE

Environmental and population growth pressures are contributing to long range changes in forest land management practices which reduce the harvest of wood for wood products and for pulp and paper manufacture (1). Consequently, the actual available supply for industrial purposes has declined dramatically (2). Partial replacement of domestic virgin fiber sources comes almost entirely from increased importation of wood and pulp and by enhanced recycling, particularly of old corrugated containers, old newspaper and mixed office waste. Projections show growing shortages of some of these waste paper categories in the near future(3). Consequently, manufacturers must seriously evaluate other fiber sources. Intensively managed plantations established during the last two decades will begin to replace only some of the deficit in virgin wood fibers.

Pressures to limit wood harvest from U.S. public forest land represent a significant opportunity to integrate agricultural production and pulp and paper manufacture. Thus, interest is also growing in the U.S. to find processes by which pulps from agricultural residues such as the cereal grains can be produced and blended with higher quality wood fibers for paper and paperboard production. Integration of agricultural production and pulp and paper manufacturing potentially could reduce the pressure on forest harvesting and at the same time produce added value products from underutilized residues while contributing to rural development and income. In Washington state(and the Pacific Northwest) wheat straw is the dominant agricultural residue. Consequently, this proposal will focus on that material. Other residues such as other cereal grains, grass and alfalfa seed straw and corn may also find use as pulp raw materials and these will be explored in this study for bleachable grades such as newsprint pulp.

The first step in an integrated agripulp system would involve conversion of wheat straw to pulp for partial substitution into paper products. In addition, by selection of a sodium-free pulping process/s further integration may include processing of the spent pulping chemicals into a form compatible with soil application as fertilizers. These pulping chemicals are rich in carbon and sulfur and could incorporate potassium, ammonia and other nutrients. Evidence from our early laboratory and green house studies shows that soil application of sodium-free spent pulping liquors has the potential to increase soil carbon, plant growth and soil aggregation with improved resistance to soil erosion(4).

Excess straw associated with wheat in the highly productive Northwest regions poses significant management problems. The supply of straw far exceeds demand for low cost uses such as bedding or livestock feed supplement. Recycle by tillage is expensive in terms of time, machinery wear, increased nitrogen fertilizer costs and labor costs. Furthermore, the diesel fuel usage associated with tillage consumes a non renewable resource(diesel fuel)and produces carbon dioxide as a combustion product. Conversion from tilled to No-Till systems could reduce carbon dioxide emissions associated with diesel fuel combustion by about 10 pounds of $CO_2$ per acre. This amounts to about 40 million pounds per year associated with Washington state wheat production. Public

appreciation of such a quantity of greenhouse gas could help keep this nation on track for ratifying treaties to reduce emissions altering global and regional climate.

However, the heavy straw yield in the Northwest requires removal for successful No-Till operations. The least expensive straw removal involves field burning. Currently, about 2 million acres of wheat are grown in Washington with straw yields of 3 to 4 million tons per year. Presently about 200,000 acres of wheat stubble is burned per year in those regions. This results in atmospheric emissions of about 45,000 tons of particulates, carbon oxides and volatile carbon compounds (5).

Conversion of the residue to pulp and paper products with return of the spent pulping chemicals to the soil would be compatible with No-Till agronomic methods. Furthermore, soil carbon content could be maintained by the application of carbon-rich spent chemicals. Higher application rates could be used on carbon-depleted sites such as steep hill gradients. Finally, spent pulping chemicals (described later) placed on the soil strongly aggregate soil and would retard erosion rates.

Clearly, an integrated agripulp system offers potential economic and environmental improvements to the agricultural and forest products communities as well as to our common environment. However, mechanical and chemical differences between wood and wheat straw require some attention to technical, infrastructure and economic challenges.

## BARRIERS TO STRAW UTILIZATION IN PULP AND PAPER

Straw residue consists mostly of stems, leaves, sheaths and nodes. These materials are a heterogeneous matrix of cellulose (≈42%), hemicellulose (≈32%) and lignin(≈22%) and small amounts of extractives. Separation of the plant stem material into fibers by softening and removing a portion of the lignin results in brown colored pulp which can be used in products such as corrugated medium and liner board for boxes. Bleaching to remove the residual lignin produces bright pulps which can be used in printing and communication papers.

Technical barriers to economic pulp and paper production from straw include:1) an efficient system for harvest, storage, transport to the mill site. 2)control of silica in the process equipment. 3)produce paper products with equivalent properties to wood derived papers. 4)chlorine free bleaching systems for straw pulps. These barriers are addressed in the following Grant Application and in suggested future work.

## PROPOSED WORK

Industry recognizes the potential value of the large quantities (≈51 million tons in the U.S.) of utilizable wheat straw that goes to waste in the U.S. each fall. Cost effective utilization of that raw material has been limited by several factors. First, existing pulp and paper production capacity is currently satisfied by wood sources and by recycled paper. So, the opportunity for use of non-wood fibers has been limited by a combination of supply and price of the traditional raw materials. However, forecasts strongly suggest future shortages in both wood and in recycled paper in western U.S. This development could lead to greater use of alternate raw materials such as wheat straw. Second, the large pulp and paper manufacturing facilities require massive daily deliveries of raw material. The industry has been concerned about timely collection, storage and delivery of the bulky straw to manufacturing sites. Recent work in the Willamette Valley with rye grass straw has demonstrated technology to overcome these problems. Furthermore, a recently funded Dept. of Energy project anticipates modification of harvesting systems to accommodate the needs of industrial users of straw residues(6). Third, the industry has had limited information on the physical and chemical character of Pacific Northwest straw residue. As a result it was difficult to forecast the impacts of this new material on process equipment which was designed for wood. Recent studies have clarified the chemical composition which will affect processing and the straw morphology which influences paper properties(7). Furthermore, soil application of the spent materials in greenhouse studies have been encouraging(4).

So, we can anticipate a need for different raw material mixes into pulp and paper manufacturing. But, typically the pulp and paper mill customers rely on paper with unchanging and uniform paper performance properties. They require full-scale demonstration of any changes in raw material or process conditions before accepting delivery of products, which were formerly manufactured under significantly different conditions. Full scale mill trials are expensive, particularly if the product produced in the trial is off-grade(i.e., it can not be sold). For example, the lost income on a paper machine producing off grade paper amounts to $125 per minute. Consequently, the work proposed in this Grant Application is focussed on demonstrating the use of cereal straws pulped for a individual paper product, which can be made with minimum disruption of the normal paper mill operations. Corrugated medium is attractive because:

- It is a paper product, which has low sensitivity to raw material composition.
- It is a product, which will require the least modification of manufacturing conditions.
- Several mill locations producing corrugated medium are currently or will soon have raw material shortages.

The work proposed in this Grant Application is divided into three Phases.

1. PHASE I

The first target product is corrugated medium (the fluted material in cardboard containers). About 600,000 tons per year of this product is manufactured in the Pacific Northwest. Our preliminary work suggests that wheat straw pulp could be substituted in corrugated medium up to about 50% with little or no change in properties. (At this usage rate, the 300,000 tons of wheat straw pulp would correspond to about 1/5 of the available Washington State material). Of course, larger scale trials are required to confirm those results. The Ponderosa Fibers mill (currently under reorganization) manufacturing site at Wallula, Washington had experienced some raw material shortage and has expressed interest in evaluating wheat straw as a partial wood pulp substitute. In addition, Stone Container at Missoula, Montana and Georgia Pacific at Toledo, Oregon have raw material needs.

PHASE I of this project includes laboratory work to support a larger scale trial at the mill. It is divided into two parts. Sodium hydroxide and potassium hydroxide versions of Universal Pulping will be done to determine conditions under which the pulp properties will be optimized for use in corrugated medium. In addition, the optimum conditions should leave the silica in the straw and not dissolve it into the spent pulping liquor. This information will allow the mill to plan full scale pulping with little or no silica deposits on the process equipment and will help to minimize the disruption of normal mill operations..

The second part of PHASE I will be production of about 50 pounds of corrugated medium with a range of straw/wood ratios on the University of Washington paper machine. This will be tested, fluted and converted to combined board for further testing. These results will confirm on larger laboratory scale the viability of straw in this product. The final result of this 6 month phase will be a report intended to help Boise Cascade (or other mill sites) move forward with a large scale mill demonstration.

2. PHASE II

- Evaluate seed alfalfa, grass, and barley straw for strength properties
- Determine an optimum bleaching sequence for each of these straws
- Determine a match for each straw type and a corresponding paper grade

Phase II of this project includes laboratory work to develop a bleached straw pulp. Preliminary investigations showed that seed alfalfa straw gave higher unbleached brightness and may be a viable raw material for newsprint pulp. Bleaching conditions will be optimized for all straw types. The straws to be evaluated have different fiber properties, and will bleach and respond differently. This will require fiber length analysis, and an evaluation of bleached and unbleached pulp strength.

The second part of Phase II would be to produce enough bleached pulp to manufacture a newsprint grade of paper with varying amounts of bleached straw pulp. This paper will be tested and printed. These results will confirm on a larger laboratory scale the viability of straw in this product.

## 3. PHASE III

Frequently, development work at the laboratory stage proceeds without a clear path forward towards commercial utilization of the findings and can result in inadequate development of information for subsequent step. Consideration of how the technology can be applied will be a feature of this project from the beginning and Phase III will be to develop a commercial trail plan and cost.
As the project develops in Phases I and II, contacts with Northwest mills will be made and potential locations for a commercialized trial will be identified. Once a suitable location id selected and the cooperation of the company established, evaluation of process equipment needs, existing facilities and any additional equipment will be made.

A detailed trial plan will be developed and all cost associated with running the trial will be estimated so that the company can make a sound decision as to the merits of going ahead with the plan. In this way the laboratory work will tie in closely with the realities of the commercial arena.

Specific actions involved in Phase III will be:

- Assess existing facilities and equipment and identify the necessary modifications required for a mill trial.

- Engineer modifications of the Ponderosa Fibers facility for a mill trial

- Design and cost the modifications to mill equipment required for pulping, pulp processing and paper machine trials

- Make cost estimates for a short term, full scale mill trial to produce a bleached grade of pulp.

## PHASE IV

Washington State University will design and evaluate field tests with spent liquor from the laboratory pulp trials. They will also evaluate on a larger scale, a fertilizer produced from the subsequent mill trial. This will be done at their cooperative research sites and interested farmers.

During PHASE I we will continue discussions with the mill locations to help plan a full scale trial/s leading to production of enough corrugated medium for customer testing. The focus in those discussions will be on minimizing technical problems during the trials which would upset their normal mill operations. Any mill trial is disruptive and expensive unless these disruptions are addressed early. But, when mill management perceives benefits they are open to surprising amounts of experimentation at considerable cost.

SUMMARY

The proposed work described in this Grant Application will develop technical information to help a pulp and paper manufacturing mill plan for a short term, full mill trial using cereal straws as a part of the raw material mix. These trials would partially substitute cereal straw for wood pulp in corrugated medium and in newsprint. The quantity of material produced would be sufficient for broad distribution to corrugated medium consumers. Enough newsprint would be manufactured to have samples for both newsprint manufacturers and publishers. Currently there are two newsprint manufacturers in eastern Washington. In addition, the project will begin discussions with public agencies about the economic and environmental advantages resulting from incorporations of agricultural residues into paper products.

## WORK PLAN AND SCHEDULE

PHASE I will require about six months with the focus on acquiring technical information necessary to plan a full scale mill trial. The pulping portion of PHASE I will include about 25 cooks to identify optimum time, temperature and chemical composition to obtain acceptable corrugated medium properties at the highest yields possible. In addition, we will identify the best conditions to retain silica in the pulp and to avoid dissolution into the spent pulping chemicals.

PHASE II will start about two months into the pulping trials by attempting to bleach straw to 65 brightness. Approximately 10-15 bleaching sequences will be evaluated to decide upon the best approach. This approach will then be applied to all of the straw types being evaluated. This will last about nine months.

PHASE III will involve engineering and modifications to handle straw, planning mill trial/s and acquiring straw supply for the trials. We anticipate a considerable interest in the farming community and a ready supply of straw for this project.

PHASE IV will start at a predetermined time as best to apply fertilizer. Data collection will occur at on various plant types at the research sites.

## BUDGET

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| PHASE I | $12,000 |
| PHASE II | $14,000 |
| PHASE III | $10,000 |
| PHASE IV | $10,000 |
| ADMINISTRATION AND FINAL REPORT | $ 4,000 |
| **TOTAL** | **$50,000** |

Notice that the expenses in PHASES I & II include only supplies and hourly labor associated with the work outlined in each Task. This does not include salaries for Dr. McKean and Mr. Lewis which are covered by the U.W. Supervision, travel and communication costs associated with PHASES I & II are covered from existing UW funds.

## LITERATURE CITED


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7. Jacobs, R. S., "The Papermaking Properties of Washington State Wheat Straw", PhD Thesis, University of Washington, 1999.

## ACCOMPLISHMENTS, CAPABILITIES AND QUALIFICATIONS OF APPLICANTS

1. LEWIS ENGINEERING CONSULTANTS

Lewis Engineering Consultants is an engineering firm concentrating on structural, mechanical engineering and providing project management and technical assistance to the pulp and paper industry.

2. PULP AND PAPER CENTER, UNIVERSITY OF WASHINGTON

The Pulp and Paper Center is part of the Paper Science and Engineering Group at the University of Washington and is the only facility of its kind in the western U. S. The Center contains equipment and test facilities to process most fiber raw materials into pulp, to bleach by conventional and chlorine free sequences, to manufacture small quantities of paper (less than about 50 pounds) on small paper machines. In addition, the facilities are present for full chemical and physical testing of raw materials and products. This group has been active in undergraduate and graduate education related to pulp and paper, nonwoven and composite materials for about 50 years. It is recognized throughout the world as a leader in education and research in those areas.

The first major commercial non-wood pulp run was recently completed at the Samoa Pacific mill in northern California. All of the research leading up to that run was completed at the University of Washington Pulp and Paper Center. The raw material used was Arundo donax, and plant, which can be grown in plantations in many states, including Washington.